



TDEC Review (June 15, 2020)
Draft Waste Acceptance Criteria
Proposed Environmental Management Disposal Facility
Oak Ridge, Tennessee

The Tennessee Department of Environment and Conservation (TDEC) offers this review to support dialog with the U.S. Department of Energy (DOE) - Oak Ridge Office of Environmental Management (OREM). The goal is to develop protective Waste Acceptance Criteria (WAC) for the proposed Environmental Management Disposal Facility (EMDF) before OREM issues a draft (D1) Record of Decision (ROD). Protective WAC are needed to show that EMDF would protect people from radiation-induced cancer and health effects from hazardous & toxic chemicals.

In 2018, OREM issued a proposed plan¹ that describes TDEC's concerns, including the need to evaluate WAC to protect people from exposure to radioactive material, now and in the future. In 2019, OREM provided draft WAC information from the forthcoming ROD and requested TDEC's feedback.² TDEC engaged Neptune and Company, Inc. (Neptune) as subject matter experts (SMEs) to review OREM's proposed WAC and determine whether the criteria meet the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).³ Neptune has extensive experience with complex radioactive waste-disposal challenges faced by DOE and other entities throughout the U.S. and around the world. Neptune identified opportunities for improving the proposed WAC.

The following pages summarize the findings of the preliminary review. TDEC may offer additional feedback following review of the recently finalized Performance Assessment (PA)⁴ and Composite Analysis (CA)⁵. Those reports should provide information vital to understanding the protectiveness of the proposed WAC.

¹ *Proposed Plan for the Disposal of Oak Ridge Reservation Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Waste* (DOE/OR/01-2695&D2/R1); available at <https://doeic.science.energy.gov/uploads/A.0100.030.2596.pdf>.

² Draft WAC information from the forthcoming *Record of Decision for Comprehensive Environmental Response, Compensation, and Liability Act Oak Ridge Reservation Waste Disposal at the Environmental Management Disposal Facility, Oak Ridge, Tennessee* (DOE/OR/01-2794&D1) (shared with TDEC on July 30, 2019).

³ Commonly known as "Superfund," CERCLA is the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986.

⁴ *Performance Assessment for the Environmental Management Disposal Facility at the Y-12 National Security Complex, Oak Ridge, Tennessee* (UCOR-5094/R2); April 28, 2020 (shared with TDEC on May 18, 2020).

⁵ *Composite Analysis for the Environmental Management Waste Management Facility and the Environmental Management Disposal Facility, Oak Ridge, Tennessee* (UCOR-5095/R2); April 29, 2020 (shared with TDEC on May 18, 2020).

Administrative WAC

- Draft ROD text does not describe how DOE would manage the waste to avoid spontaneous criticality, a self-sustaining nuclear chain reaction.
- Draft ROD text does not say whether EMDF would accept hazardous waste, nor does it discuss waste treatment to stabilize and/or immobilize hazardous chemicals like mercury. Missing information includes contaminants that may require treatment, anticipated waste forms, and proposed limits on hazardous contaminants. All are critical to understanding how EMDF would protect people and the environment, now and in the future.
- The ROD must state that mixed waste disposed of in the proposed EMDF will be treated using technology approved by TDEC under the existing *Site Treatment Plan for Mixed Wastes on the U.S. Department of Energy Oak Ridge Reservation (STP)*.
- The proposed WAC mentions “*free-flowing liquids*”. This phrase is not defined in regulations, although the term “free liquid” is defined and linked to a specified test method in RCRA Subtitle C regulations applied as ARARs. Source separation should be employed to recover elemental mercury as a liquid. There are alternate treatment methods for debris, soils and high- and low-concentration categories of RCRA D009 mercury characteristically hazardous waste. Compliance with ARARs related to land disposal restrictions (LDRs) for mercury and the regulations prohibiting disposal of liquids in a hazardous waste should be better delineated and described for different forms of mercury waste and contaminated media.
- Limits on polychlorinated biphenyl (PCB) liquid disposal need clarification to ensure compliance with TSCA ARARs. As currently worded, it is not clear that liquids with more than 50 parts per million (ppm) PCBs must be treated so they will not flow and that liquids with more than 500 ppm PCBs must not be placed in the landfill under any circumstances.

Analytic WAC

- Draft ROD text does not include analytic WAC for hazardous and toxic chemicals likely to be in EMDF waste, such as mercury & PCBs. WAC may be necessary to decrease concentrations of such chemicals in landfill wastewater to meet ROD requirements for treating landfill wastewater to protective levels before discharging it into local streams. DOE should evaluate whether WAC

limits are needed for chemicals like mercury to ensure selected technologies can treat landfill wastewater to protective discharge levels.

- It is not clear the draft WAC account for radionuclides that contribute substantially to the radiation dose the public could receive from the waste or from wastewater that flows downstream. Some progeny (nuclides produced through radioactive decay) produce more radiation dose than their parent radionuclides.⁶ For such radionuclides, protecting the public requires more than limiting the amount of radioactivity the waste produces upon disposal. In such cases, protectiveness requires limits on the amounts (inventories) of specific radionuclides placed in the landfill. This is necessary to account for the radiation dose produced by the parents and their progeny over time *in addition to* the dose produced upon waste disposal.

For example, determining safe amounts of plutonium-241 (Pu-241), americium-241 (Am-241), and neptunium-237 (Np-237) for disposal must account for the fact that Pu-241 (14-year half-life) decays to Am-241, which increases the amount of Am-241 in the waste. Americium-241 (half-life about 430 years) decays to Np-237, increasing the amount of that radionuclide. Neptunium-237 produces a lot more dose than Pu-241 or Am-241, so it poses a much greater threat. Moreover, Np-237 is a threat for a much longer time because it has a half-life greater than 2 million years. Failure to consider the amount of a specific radionuclide when setting limits for others in the same “decay chain” could result in unacceptable radiation doses to the public. It is not enough to set limits for each radionuclide in isolation; limits for all radionuclides in the decay chain must be considered based on the combined threat. If Am-241 were disposed at its WAC limit, that limit would be exceeded within a few decades as more Pu-241 decays and produces more Am-241. The same is true for Np-237, with an even longer half-life. There are many other examples of this this fundamental concept.

- Draft WAC include radioactivity limits for 48 radionuclides to ensure protectiveness if someone digs into the waste in future.⁷ However, the text says when setting WAC to ensure protectiveness if there is a release from the landfill, OREM will track and limit the total amount (inventory) of only three radionuclides: tritium (H-3), technetium-99 (Tc-99), and carbon-14 (C-14) because PA model results show they are the only ones that may escape from the landfill and reach the highest concentrations within 1,000 years. This finding is unusual. PA models for most radioactive waste disposal facilities find that

⁶ A nuclide is a distinct kind of atom. Some are stable, and others are radionuclides, meaning they are radioactive. Radionuclides have excess nuclear energy. They are unstable and decay to produce other nuclides, some of which may also be radioactive. In this case, dose refers to the radiation absorbed by people exposed to radionuclides in radioactive material.

⁷ Table 2.6 lists 48 radionuclides, but the text says OREM considered 49 radionuclides in the assessment.

many more radionuclides may escape, even though the facilities are typically in drier (desert) locations in the western U.S., where lesser amounts of rain cannot flush contaminants into surrounding areas as easily as higher rainfall amounts can in Oak Ridge. The WAC should be modified to:

- **Track all radionuclides in the inventory.** The plan to track only three radionuclides is inadequate. OREM must track the amount of all radionuclides identified in waste profiles and placed in the proposed EMDF landfill to document the total inventory.⁸
 - **Limit many radionuclides based on mobility, bioaccumulation or other risk factors.** OREM should limit the inventory of radionuclides with the greatest potential to harm streams, fish, and people because of their ability to travel, accumulate, or cause cancer or other health effects in the future. Attachment 1 presents examples of radionuclides that may need inventory limits to protect people who eat fish caught downstream of EMDF after DOE no longer controls the area.
 - **Establish flexibility to limit additional radionuclides during operations based on new information.** There should be a means to add WAC requirements, including inventory limits, for additional radionuclides if needed. For example, radionuclides projected to have negligible inventories may be disposed of in greater quantities than originally anticipated, and additional radionuclides may be found to be significant at Oak Ridge National Laboratory (ORNL) or other waste sources.
- Draft ROD text says, *"Class C concentration limits are more restrictive (lower) than limits based on the EMDF intrusion performance analysis for 13 radionuclides (Table 2.6)."*⁹ This suggests DOE's calculations would allow radioactive waste in the proposed EMDF to exceed Class C limits. The ROD must specify that OREM would not place Greater-Than-Class-C (GTCC) waste in the proposed EMDF. GTCC waste generally requires more protective disposal methods, such as burial in a deep geologic repository like the Waste Isolation Pilot Plant (WIPP) in New Mexico, to make it safe for public health and the environment.

⁸ OREM reports not knowing the true Environmental Management Waste Management Facility (EMWMF) inventory because it tracks only a few radionuclides for that landfill.

⁹ The Nuclear Regulatory Commission (NRC) considers three classes of low-level radioactive waste suitable for burial in a landfill. Class A has the least radioactivity, most of which decays to background levels within a few decades. Class B has more radioactivity than Class A, and Class C has even more radioactivity than Class B. <https://www.energy.gov/sites/prod/files/2019/06/f63/Nuclear-Regulatory-Commission%E2%80%99s-Low-Level-Radioactive-Waste-Classifications-June-2019.pdf>

- Draft ROD text also suggests EMDF might allow disposal of waste that does not comply with WAC. OREM must not dispose of waste with radioactivity above compliance standards.
- The proposed WAC do not account for uncertainties in the projected amounts of radioactivity the waste would contain. OREM should follow common practice to manage uncertainty by using defensible statistical methods, such as the use of 95% confidence intervals instead of simply averaging projected levels of radioactivity. Establishing protective WAC requires DOE to understand how much of the waste may have above-average radioactivity levels.
- The proposed WAC are based on scenarios that do not assess increased public health risk from uranium's toxicity, which poses more potential short-term risk of health effects than uranium's cancer-causing radioactivity.
- The proposed WAC are also based on scenarios that do not assess public exposure to higher radioactivity and greater cancer risk because some radionuclides bioaccumulate in fish. Bear Creek sustains populations of rock bass and perch, both of which are fished for consumption.
- Draft ROD text proposes WAC without consideration of important natural processes like erosion. This is a significant deficiency because erosion could expose people to substantial radiation doses in the future by uncovering waste and carrying contamination downstream. The ROD should develop WAC based on evaluation of realistic erosion rates. Public exposure to eroded wastes would not depend on cap thickness or require someone to dig a residential basement into the waste, as suggested in the draft ROD text.
- A table in the draft ROD text presents limits on the amount of radioactivity someone could encounter upon accidentally discovering the waste in the future. However, the text does not explain how DOE established these limits. TDEC and the public need the DOE to "show your work" to verify the accuracy and protectiveness of these "intrusion-based" WAC.

Operations-Based WAC

- Along with DOE, TDEC & the U.S. Environmental Protection Agency (EPA) should be involved in defining and approving operations-based WAC. Consensus and transparency would eliminate conflicts of interest that exist when the party generating the waste has sole responsibility for

deciding whether that material meets WAC at a landfill operated by the same party. Regulator involvement in the process, consistent with the Federal Facility Agreement for the Oak Ridge Reservation (FFA), would support the oversight needed to ensure WAC compliance.

Conclusion

TDEC is required by law to determine whether the ROD for the proposed landfill is meets CERCLA threshold criteria of protectiveness and compliance with ARARs. Before TDEC can approve a ROD that authorizes landfill construction, OREM must correct deficiencies in the WAC described above to show the EMDF would protect people from radiation-induced cancer, as well as health effects from hazardous & toxic chemicals.

Recommendations

In the spirit of partnership, the TDEC offers several recommendations for establishing protective WAC in the ROD and ensuring future waste disposal complies with those WAC.

- Obtain a Preliminary Disposal Authorization Statement (PDAS) demonstrating that DOE Headquarters finds the proposed EMDF would perform in a manner that protects the public from exposure to unacceptable radiation doses in accordance with DOE Orders. Before signing the ROD, TDEC needs to verify that PA & CA modeling used to develop WAC supports the requirements of CERCLA, including protecting people who catch and eat fish downstream.
- State in the ROD that the hazardous component of mixed waste disposed of in the proposed EMDF must be treated using technology approved by TDEC under the existing STP.
- Establish protective limits on the release of hazardous contaminants like mercury to local streams and/or treatment of waste before disposal.
- Protect receptors from uranium's non-cancer health effects, which pose more risk in the short term than its cancer-causing radioactivity.
- Limit the inventory of radionuclides with the greatest potential to harm streams, fish, and people because they can travel, accumulate, or cause cancer or other health effects. Attachment 1 presents examples of radionuclides that may need inventory limits.

- The ROD must require a comprehensive program that monitors radionuclides and other hazardous contaminants in fish and uses CERCLA guidance to evaluate potential risks to people consuming fish caught downstream. The program must include ways to inform the public of any risks, including posting streams with unacceptable risks and contingencies for corrective action including, but not limited to, closing EMDF if necessary to decrease unacceptable risks.
- The ROD must state that OREM will track the amounts of all radionuclides identified in waste profiles and placed in the proposed EMDF landfill, including radioactive decay progeny, to determine the total amount of radioactivity in the EMDF at any time and to document the total inventory upon closure.
- Specify that OREM will not place Greater-Than-Class-C waste in the proposed EMDF.
- Involve TDEC & EPA in defining and approving operations-based WAC.
- Include language in the ROD obligating OREM to:
 - Submit a primary document under the FFA that lays out requirements for an independent WAC compliance plan for approval by EPA & TDEC; and
 - Implement independent WAC compliance with regulatory oversight, including establishment of an independent WAC compliance team with authority to direct waste characterization efforts and waste profile development.

Attachment 1

Preliminary List of Radionuclides Needing Inventory Limits at the Proposed Environmental Management Disposal Facility (EMDF) Tennessee Department of Environment & Conservation (TDEC)

The Tennessee Department of Environment & Conservation (TDEC) developed a list of radionuclides (Table 1) that need inventory limits as the U.S. Department of Energy (DOE) sets waste acceptance criteria (WAC) for the proposed Environmental Management Disposal Facility (EMDF) in Oak Ridge. TDEC prepared the list because of the need to protect people who eat fish caught near the proposed EMDF site *in the future*, as required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).^{10,11} The proposed EMDF site, also known as the Central Bear Creek Valley site, lies on Bear Creek downstream of two existing disposal sites—Bear Creek Burial Grounds (BCBG) and the Environmental Management Waste Management Facility (EMWMF).

TDEC applied the following assumptions in developing the list in Table 1.

- EMDF waste cells will occupy 23 acres, as projected in the EMDF D5 remedial investigation/feasibility study (RI/FS).
- The EMDF landfill returns to a more natural condition in the future—e.g., 250, 1,000, or 10,000 years.
- The natural recharge rate is 9.4 inches per year, the average measured in the Poplar Creek watershed near Oak Ridge and published by the U.S. Geological Survey (USGS).¹²
- Given that Bear Creek is designated for recreational use, stream flow was estimated using USGS StreamStats¹³ based on the “30-day minimum five year recurrence interval,” per Tennessee Comp. R. & Regs. 0400-40-03-.05(4).
- A person eats 24 ounces (oz), which is three 8-oz or four 6-oz servings, of fish caught downstream each month for 26 years.
- An acceptable excess lifetime cancer (ELCR) of “ 10^{-5} risk level is used for all carcinogenic pollutants,” per Tennessee Comp. R. & Regs. Rule 0400-40-03-.03(4)(j).
- Bioconcentration factors (BCF) are the geometric means of International Atomic Energy Agency (IAEA) / International Union of Radioecologists (IUR) values, which are updates to the IAEA BCF values in the Oak Ridge National Lab (ORNL) Risk Assessment Information

¹⁰ While it is reasonable to assume members of the public are unlikely to access controlled portions of the Oak Ridge Reservation upstream of Highway 95 on a routine basis during landfill operations, that assumption is neither reasonable nor consistent with CERCLA risk assessment guidance for evaluating periods after DOE no longer controls the land use.

¹¹ CERCLA is a set of laws Congress created to clean up the most polluted sites in the country. Commonly known as “Superfund,” CERCLA is the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986.

¹² Hoos, A.B., 1990, Recharge Rates and Aquifer Hydraulic Characteristics for Selected Drainage Basins in Middle and East Tennessee: U.S. Geological Survey Water-Resources Investigations Report 90-4015, 34 p. (available at https://pubs.usgs.gov/wri/wri90-4015/pdf/wrir_90-4015.pdf)

¹³ Available at <https://streamstats.usgs.gov/ss/>.

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System (RAIS) and U.S. Environmental Protection Agency (EPA) Preliminary Remediation Goals for Radionuclides (PRG) calculator.¹⁴

TDEC's evaluation proceeded as follows.

- Evaluate radionuclides the EMDF D5 RI/FS projects will have non-negligible inventories.
- Estimate releases (by isotope) that may cause a 10^{-5} excess cancer risk if the landfill returns to a more natural condition in 250, 1,000, or 10,000 years.
- Assess fish consumption risk using the EPA radionuclide PRG calculator with default assumptions, except the fish ingestion rate, risk level, and BCF values described above.
- Calculate average initial radionuclide concentrations in the waste that would decay to concentrations associated with the 10^{-5} risk level in 250, 1,000, and 10,000 years.
- Identify long-half-life radionuclides with high partition coefficients (K_d) and BCF values to identify isotopes with "uncertain" long-term fish consumption risks.
- Review the radionuclide list in the D3 RI/FS to determine if additional long-half-life radionuclides with elevated BCF and K_d values need further evaluation.
- Determine radionuclides of potential concern during the 1,000- to 10,000-year period by comparing calculated inventories (in curies) that may be disposed of without exceeding the 10^{-5} risk level with the projected inventory from the D5 RI/FS.¹⁵
- Repeat evaluation as if EMWMF and BCBG would be the only disposal sites in Bear Creek Valley.

Table 1 presents the radionuclides of potential concern, including long-half-life isotopes that may be present at EMWMF and BCBG in sufficient quantities to warrant more thorough evaluation. These isotopes need additional evaluation to determine whether the combined inventories of EMDF, BCBG, and a future EMDF would exceed the 10^{-5} risk level, which would violate Tennessee Comp. R. & Regs. 0400-40-03-.03(4)(j) and, thus, the CERCLA requirement for overall protection of human health.

TDEC also evaluated K_d and BCF values to identify isotopes with "uncertain" long-term fish consumption risks. Radionuclides with high K_d values tend to sorb to sediment and organic matter. They move downstream with sediment load and may stay in the creek longer. BCF values indicate bioconcentration in the food web. BCF values for some radionuclides vary by orders of magnitude, so TDEC used central-tendency values (geometric means) where available.

TDEC's evaluation retained several radionuclides that the D5 RI/FS screened out. For example, the D5 RI/FS screened out chlorine-36 (Cl-36) and potassium-40 (K-40) due to negligible inventory, yet both isotopes have been detected in EMWMF discharge at the V-Weir. Further, the K-40

¹⁴ Available at https://epa-prgs.ornl.gov/cgi-bin/radionuclides/rprg_search.

¹⁵ For many of the radionuclides, half-lives are long enough to prevent significant change in the inventory associated with the 10^{-5} risk level from 250 to 10,000 years.

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detection limit for V-Weir analyses is insufficient to evaluate risk. Neither Cl-36 nor K-40 requires a large inventory to pose potential risk to people eating fish caught downstream.

The D5 RI/FS also screened out Cesium-135 (Cs-135) as having a negligible inventory. The inventory may appear negligible due to the challenge of analyzing Cs-135 in the laboratory. Table 1 includes Cs-135 because it is a fission product formed with Cs-137, which is in the projected inventory. If there is a substantial quantity of Cs-137 in the waste, there may also be a substantial quantity of Cs-135. Moreover, Cs-135 has a half-life of 2,300,000 years, much longer than the 30.17 half-life of Cs-137. Cs-134, Cs-135, and Cs-137 have relatively high K_d and BCF values and are important considerations for the downstream fishing exposure pathway.

The list of radionuclides in Table 1 is not a complete list of isotopes that require monitoring during the operational and post-closure periods. Table 1 excludes most radionuclides with shorter half-lives because landfill wastewater treatment, operations, and post-closure care should protect people fishing downstream during the short term. The list of radionuclides in Table 1 focuses primarily on (1) long-half-life radionuclides (1,000 to 10,000-year evaluation), (2) radionuclides with potentially large inventories, and (3) radionuclides identified as concerns due to combinations of BCF, K_d , and toxicity. Cs-135 was also added due to characterization uncertainty and its potential impact on fish consumption risk.

Table 1 lists the radionuclides that appear to need inventory limits at the proposed EMDF landfill to protect people who eat fish caught downstream after DOE no longer controls the area. There should be a means to add WAC requirements, including inventory limits, for additional radionuclides, if needed. For example, radionuclides projected to have negligible inventories may be disposed of in greater quantities than originally anticipated, and additional radionuclides may be found to be significant at ORNL or other waste sources.

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Isotope	Half-life (years)	Seven Half-lives (years)	1,000- to 10,000-year Evaluation	Comment
Americium-241 (Am-241)	432.2	3,025	Potential Concern	
Americium-243 (Am-243)	7,370	51,590	Potential Concern	
Carbon-14 (C-14)	5,700	39,900	Potential Concern	(1) Detection limits for C-14 in CY2019 at EMWMF V-Weir are often insufficient to determine risk at 10^{-5} . (2) Evaluate C-14 at EMWMF and combined impact with proposed EMDF on risk from consuming fish caught in Bear Creek. EMDF inventory should incorporate C-14 disposed of at EMWMF.
Chlorine-36 (Cl-36)	301,000	2,107,000	Potential Concern	Periodically measured in discharge at EMWMF V-Weir
Curium-245 (Cm-245)	8,500	59,500	Uncertain	High K_d (9,000 L/kg); low BCF (0.24 L/kg) BCF based on limited data (7 samples in 1 reference)
Curium-246 (Cm-246)	4,760	33,320	Uncertain	High K_d (9,000 L/kg); low BCF (0.24 L/kg) BCF based on limited data (7 samples in 1 reference)
Curium-247 (Cm-247)	15,600,000	109,200,000	Uncertain	High K_d (9,000 L/kg); low BCF (0.24 L/kg) BCF based on limited data (7 samples in 1 reference)
Cobalt-60 (Co-60)	5.3	37	No	Large inventory released at ORNL and high activity level mean inventory limits may be necessary to ensure landfill wastewater discharges can be treated to protective discharge limits
Cesium-135 (Cs-135)	2,300,000	16,100,000	Uncertain	Hard to measure fission product generated with Cs-134 and Cs-137; ORNL inventory needs re-evaluation with analytical methods sufficient to measure Cs-135 and Cs-137 atomic ratios; High BCF (1700 L/kg) and K_d (1200 L/kg)
Cesium-137 (Cs-137)	30.2	211	No	Large inventory released at ORNL High BCF (1700 L/kg) and K_d (1200 L/kg)

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Isotope	Half-life (years)	Seven Half-lives (years)	1,000- to 10,000-year Evaluation	Comment
Gadolinium-148 (Gd-148)	74.6	522.2	No	D3 RI/FS Radionuclide list; High BCF and K_d : Fish BCF of 1200 L/kg with K_d of 650 L/kg
Gadolinium-150 (Gd-150)	1,790,000	12,530,000	Uncertain	D3 RI/FS Radionuclide list; High BCF and K_d : Fish BCF of 1200 L/kg with K_d of 650 L/kg
Gadolinium-152 (Gd-152)	1.08e+14	7.56E+14	Uncertain	EMDF D3 RI/FS Radionuclide list; High BCF and K_d : Fish BCF of 1200 L/kg with K_d of 650 L/kg
Iodine-129 (I-129)	15,700,000	109,900,000	Potential Concern	
Potassium-40 (K-40)	1,251,000,000	8,757,000,000	Potential Concern	Detection limits for K-40 in CY2019 at EMWMD V-Weir are often insufficient to determine risk at 10^{-5}
Lead-210 (Pb-210)	22.2	155	As Progeny	Lead-210 will decay in a few hundred years. However, it is toxic and is progeny of Ra-226, Th-230, U-234, Th-234, and U-238.
Nickel-63 (Ni-63)	100.1	701	No	Potential for a large inventory, and 700 years is a long time.
Neptunium-237 (Np-237)	2,144,000	15,008,000	Potential Concern	
Plutonium-238 (Pu-238)	87.7	614	No	Potential for a large inventory, and 600 years is a long time.
Plutonium-239 (Pu-239)	24,110	168,770	Potential Concern	
Plutonium-240 (Pu-240)	6,564	45,948	Potential Concern	
Plutonium-242 (Pu-242)	375,000	2,625,000	Potential Concern	
Plutonium-244 (Pu-244)	80,000,000	560,000,000	Potential Concern	
Radium-226 (Ra-226)	1,600	11,200	Potential Concern	
Selenium-79 (Se-79)	295,000	2,065,000	Uncertain	D5 RI/FS screened out due to negligible inventory; High BCF and K_d : BCF (1,600 L/kg) and K_d (200 – 1,000 L/kg)
Tin-126 (Sn-126)	230,000	1,610,000	Uncertain	D5 RI/FS screened out due to negligible inventory; High BCF and K_d : BCF (400 L/kg) K_d (1,600 L/kg)

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Tennessee Department of Environment & Conservation (TDEC)

Isotope	Half-life (years)	Seven Half-lives (years)	1,000- to 10,000-year Evaluation	Comment
Strontium-90 (Sr-90)	28.79	202	No	Large inventory released at ORNL
Technetium-99 (Tc-99)	211,100	1,477,700	Potential Concern	Need to evaluate Tc-99 at EMWMF and combined impact with proposed EMDF on risk from consuming fish caught in Bear Creek. EMDF inventory should incorporate Tc-99 disposed of at EMWMF.
Thorium-229 (Th-229)	7,340	51,380	Uncertain	K _d of 3,300 L/kg and BCF of 120 L/kg
Thorium-230 (Th-230)	75,380	527,660	Uncertain	K _d of 3,300 L/kg and BCF of 120 L/kg
Thorium-232 (Th-232)	1.405E+10	9.84E+10	Potential Concern	K _d of 3,300 L/kg and BCF of 120 L/kg
Thorium-234 (Th-234)	0.066	0.46	Potential Concern	Secular equilibrium with U-238
Uranium-233 (U-233)	159,200	1,114,400	Potential Concern	
Uranium-234 (U-234)	245,500	1,718,500	Potential Concern	Need to evaluate U-234 at EMWMF and combined impact of EMWMF and proposed EMDF on risk from consuming fish caught in Bear Creek. EMDF inventory should incorporate U-234 disposed of at EMWMF.
Uranium-235 (U-235)	704,000,000	4,928,000,000	Potential Concern	
Uranium-236 (U-236)	23,420,000	163,940,000	Potential Concern	

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Isotope	Half-life (years)	Seven Half-lives (years)	1,000- to 10,000-year Evaluation	Comment
Uranium-238 (U-238)	4.468E+09	3.1E+10	Potential Concern	1) Determine U-238 inventory disposed of at EMWMF and BCBG. 2) Subtract that inventory from the U-238 inventory that may be disposed of at proposed EMDF without posing unacceptable risk through the fish consumption pathway. 3) Alternatively, the EMDF ROD could include a requirement and timeline for cleanup of BCBG.

BCBG - Bear Creek Burial Grounds
BCF - bioconcentration factor
EMDF - Environmental Management Disposal Facility
EMWMF - Environmental Management Waste Management Facility
Kd - partition (or distribution) coefficient
L/kg - liters per kilogram
ORNL - Oak Ridge National Laboratory
RI/FS - Remedial Investigation/Feasibility Study
ROD - Record of Decision